Géographie physique et Quaternaire

Raised Shoreline Phenomena and Postglacial Emergence in South-Central Newfoundland

Les lignes de rivage soulevées et l'émersion postglaciaire au centre-sud de Terre-Neuve

Возвышенный рельеф побережья и послеледниковый прирост суши на южном подережье центрального Ньюфаундленда

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Résumé de l'article

Dans la région de Burin-Hermitage, au sud de Terre-Neuve, on retrouve deux types de lignes de rivage marines soulevées: des plates-formes marines entaillées dans la roche en place ainsi que des terrasses et des plages développées dans des matériaux meubles. La plupart des plates-formes datent d'avant le Wisconsinien inférieur. Une ligne de rivage rocheuse horizontale située à 4,5 ± 1,5 m, qu'on retrouve à travers la région, fut probablement formée au cours du dernier interglaciaire. Des deltas soulevés et des épandages fluvioglaciaires côtiers, associés à des plans d'eau marins qui marquent la limite marine du Wisconsinien inférieur dans la partie nord de la zone d'étude, sont mis en relation avec des terrasses et des plages soulevées existant plus au sud dans la péninsule de Burin. L'altitude de ces formes sert à établir le mode régional d'émersion post-glaciaire. Il s'est produit une emersion de plus de 30 m dans le nord-ouest, alors que l'extrême-sud de la région est en phase de submersion.

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RAISED SHORELINE PHENOMENA AND POSTGLACIAL EMERGENCE IN SOUTH-CENTRAL NEWFOUNDLAND

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ABSTRACT Two types of raised marine shoreline features occur in the Burin-Hermitage area of southern Newfoundland — marine benches cut in bedrock, and terraces and beaches developed in unconsolidated materials. Most of the benches are older than Late Wisconsinan, and a horizontal rock shoreline at 4.5 ± 1.5 m, which occurs throughout the region, was probably formed in the last interglacial period. Raised deltas and coastal outwash deposits graded to former sea level positions, which define the Late Wisconsinan marine limit across the northern part of the study area, are correlated with terraces and raised beaches further south on the Burin Peninsula. The elevations of these features are used to define the regional pattern of postglacial emergence. More than 30 m of emergence has occurred in the northwest, but the extreme southern part of the region is undergoing submergence.

RÉSUMÉ *Les lignes de rivage soulevées et l'émersion postglaciaire au centre-sud de Terre-Neuve.* Dans la région de Burin-Hermitage, au sud de Terre-Neuve, on retrouve deux types de lignes de rivage marines soulevées : des plates-formes marines entaillées dans la roche en place ainsi que des terrasses et des plages développées dans des matériaux meubles. La plupart des plates-formes datent d'avant le Wisconsinien inférieur. Une ligne de rivage rocheuse horizontale située à 4,5 ± 1,5 m, qu'on retrouve à travers la région, fut probablement formée au cours du dernier interglaciaire. Des deltas soulevés et des épandages fluvioglaciaires côtiers, associés à des plans d'eau marins qui marquent la limite marine du Wisconsinien inférieur dans la partie nord de la zone d'étude, sont mis en relation avec des terrasses et des plages soulevées existant plus au sud dans la péninsule de Burin. L'altitude de ces formes sert à établir le mode régional d'émersion post-glaciaire. Il s'est produit une émersion de plus de 30 m dans le nord-ouest, alors que l'extrême-sud de la région est en phase de submersion.

РЕЗЮМЕ *Возвышенный рельеф побережья и послеледниковый прирост суши на южном побережье центрального Ньюфаундленда.* В районе Бурин-Хермитидж южного Ньюфаундленда встречаются два типа возвышенного рельефа береговой линии: морские отмели, вырезанные в коренных породах, а также террасы и пляжи, образованные в незатвердевших породах. Большая часть отмелей старше, чем поздний висконсин, а горизонтальная береговая линия из коренных пород высотой 4,5 + - 1,5 м, которая встречается по всему району, возможно, образовалась в последний межледниковый период. Возвышенные дельты и береговые наносы отложений соответствуют бывшему уровню моря, который очерчивается морскими пределами позднего висконсина в северной части исследуемого района и совпадает с террасами и возвышенным побережьем далее на юг на полуострове Бурин. Эти возвышенности используются для определения регионального характера послеледникового прироста суши. Более 30 м прироста суши произошло на северо-западе, но в наиболее южной части района происходит затопление суши.

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INTRODUCTION

Raised shoreline features of various kinds at numerous localities in the Burin Peninsula and Hermitage area of south central Newfoundland (Fig. 1), have been noted by several authors (JEWELL, 1939; WHITE, 1939; VAN ALSTINE, 1948; WALTHIER, 1948; POTTER, 1949; WIDMER, 1950; BRADLEY, 1954; JENNESS, 1960; GRANT, 1975), and it is clear from their brief descriptions that more than one open episode of marine erosion and deposition was involved in the formation of these features. It is evident that a distinction must be made between marine benches, which predate at least one period of widespread glaciation because they are cut in bedrock and overlain by glacial deposits, and beach deposits and terraces cut in unconsolidated materials which are of late- or post-glacial age. However, prior to our investigations (TUCKER 1976, 1979 a and b; TUCKER and McCANN, 1980; LECKIE, 1979; LECKIE and McCANN, in press) there had been no concerted effort to measure the elevations and examine the morphologic and stratigraphic relations of the various shoreline fragments with a view to elucidating the relationships between former sea levels and ice limits throughout this part of Newfoundland.

Of the earlier descriptions of raised shorelines the most complete relate to the Hermitage area, where WIDMER (1950) made excellent observations of glacial and related phenomena. He recognized that "there are probably two sets of strandlines due to two different sets of conditions. Some of the occurrences are probably Sangamon in age while the remainder are probably late Wisconsin in age" (WIDMER, 1950, p. 70), but Widmer found no evidence of tilting of the strandlines. He correctly assigned the origin of terraces and other features in the northern Bay d'Espoir area (Fig. 2) to the existence of a glacially dammed lake (LECKIE and McCANN, in press) and described the evidence of a late phase of valley glaciation. However, his interpretation of late-glacial raised shoreline features along the southern (Fortune Bay) coast of the Hermitage area was severely constrained by his adherence to the view that the zero isobase of post-glacial uplift lay north of the region (DALY, 1921; FLINT, 1940, 1947). This led Widmer to propose that the younger raised shorelines of the Hermitage area and also the Burin Peninsula were developed in a series of very large freshwater lakes impounded by massive tongues of Newfoundland and Cabot Strait ice (WIDMER, 1950, plate 9, p. 124; see also TUCKER and McCANN, 1980, Fig. 2a), which initially extended out to the Grand Banks.

JENNESS (1960) interpreted a series of raised deltas at various locations along the northern Fortune Bay coast of the Hermitage — Burin region as contemporaneous features, representing the terminations of outwash valley trains which radiated down major valleys from an ice marginal position well inland to the north. On this evidence he suggested the pattern of post-glacial emergence shown in Figure 1A, which was subsequently adopted by FLINT (1971, Fig. 13 — 10, p. 360). More recently, WIGHTMAN and COOKE (1978), in a re-

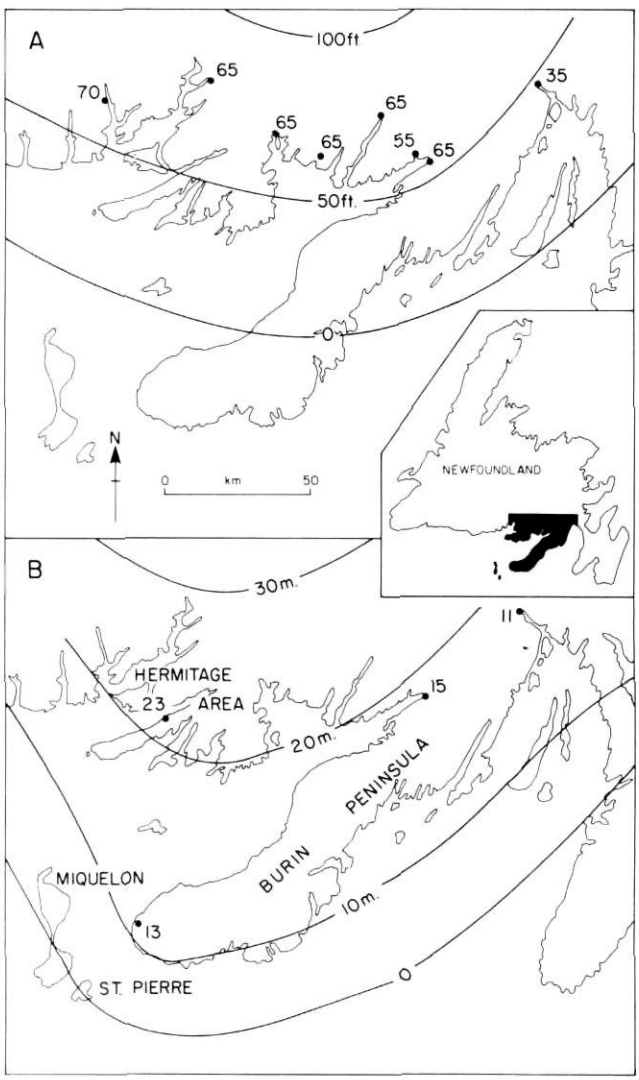

FIGURE 1. Reconstruction of the extent and amount of postglacial emergence in the Burin-Hermitage area (inset: location of study area). A. From JENNESS (1960, Fig. 8, p. 176), isobases in eastern Newfoundland, based upon upper levels of outwash deltas, and Figure 6 (p. 172), map showing location of elevated alluvial terraces in eastern Newfoundland. B. From WIGHTMAN and COOKE (1978, Fig. 2, p. 64), isopleths of postglacial emergence in Atlantic Canada.

Reconstitution de l'étendue et de l'importance de l'émersion post-glaciaire dans la région de Burin-Hermitage (carton: localisation de la région à l'étude). A. D'après JENNESS, (1960, fig. 8, p. 176), isobases dans le sud-est de Terre-Neuve, basés sur les niveaux supérieurs des deltas fluvio-glaciaires, et figure 6 (p. 172), carte montrant la localisation des terrasses fluviales soulevées dans le sud-est de Terre-Neuve. B. D'après WIGHTMAN et COOKE (1978, fig. 2, p. 64), isoplèthes de l'émersion post-glaciaire de la région atlantique du Canada.

construction of isopleths of postglacial emergence in Atlantic Canada, part of which is shown in Figure 1B, included four sites indicating the Late Wisconsinan marine limit (c. 13,500 y BP) in the Burin-Hermitage area. They do not document the sources of this information, but two of the sites, at 15 m and 11 m appear to be measurements cited by JENNESS (1960; Table 1, p. 170; Fig. 6, p. 172).

The present contribution should be regarded as a preliminary statement based on the examination of more than 950 km of coast which seeks to group the numerous raised benches, terraces, deltas and beach deposits in accordance with our interpretation of the glacial history of the region. This involves, for the Burin Peninsula and the islands of St. Pierre and Miquelon to the west, the following sequence of events, summarized in TUCKER and McCANN (1980, Table 2): 1) two phases of overall glaciation by Newfoundland-centred ice, the first being pre-Wisconsinan, or possibly Early Wisconsinan, in age, and the second Early Wisconsinan (the Fortune Bay event); 2) marine overlap in the southwest of the peninsula and the French Islands (Mid-Wisconsinan); 3) partial glaciation by ice from an offshore source to the southeast (late Mid-Wisconsinan); and 4) limited glaciation by Newfoundland-centred ice, which extended into the Gisborne Basin at the same time as small ice caps developed along the central spine of the upper peninsula, during the Late Wisconsinan.

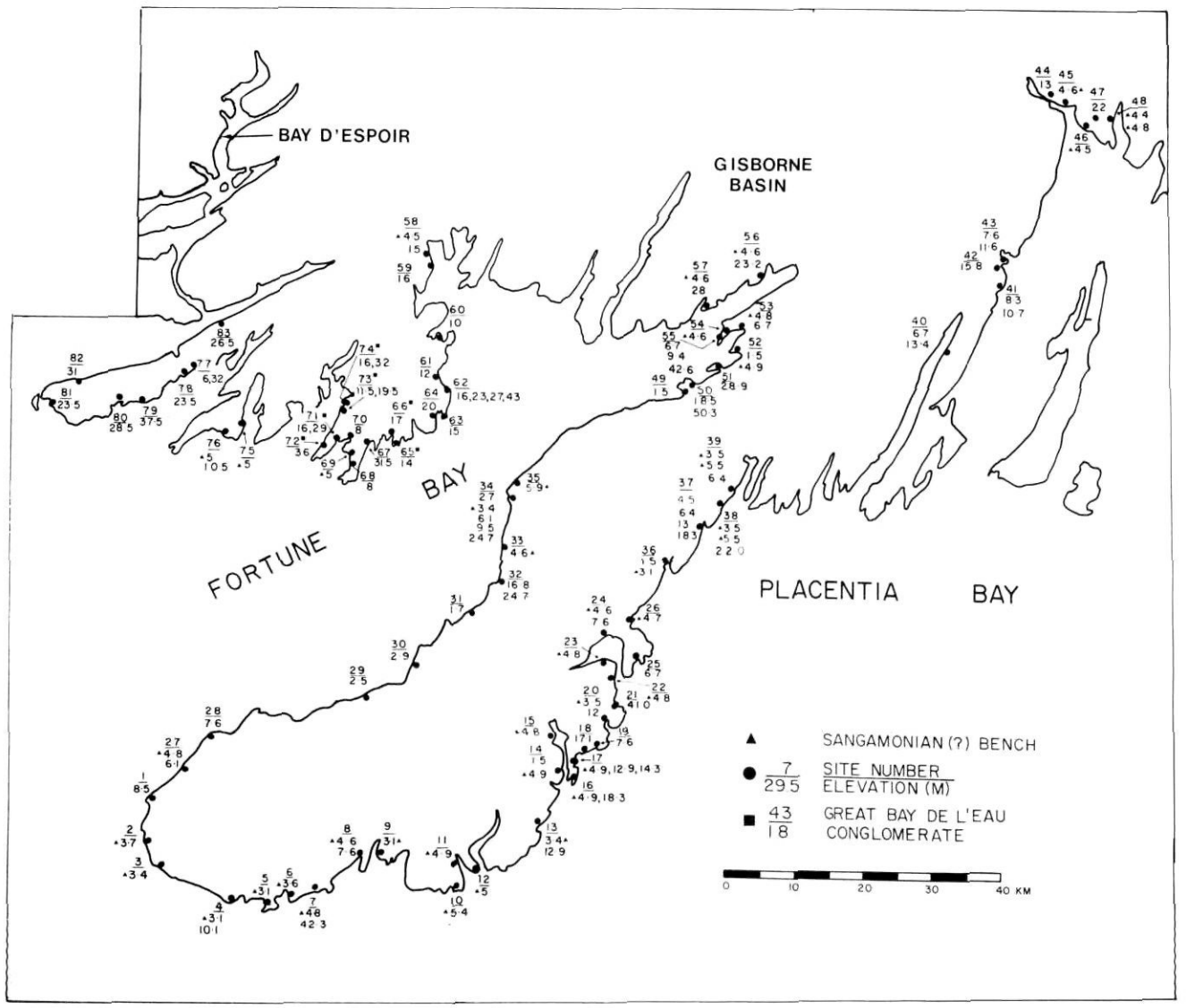

FIGURE 2. Elevations of raised marine benches in the Burin-Hermitage area of southern Newfoundland. The datum is higher, high water level of large tides.

Altitudes des plates-formes marines soulevées dans la région de Burin-Hermitage au sud de Terre-Neuve. Le point de référence est le niveau le plus élevé des eaux au moment des plus fortes marées.

This last event was represented in the southern part of the Hermitage area by mountain ice caps, with outlet glaciers which reached parts of the Fortune Bay coastline, and in the northern part by the incursion of Newfoundland-centred ice (LECKIE, 1979). The correlation of the northern Hermitage and Gisborne Basin ice marginal positions (McCANN, LECKIE and TUCKER, 1980) shown in Figure 3, is allied to the suggestion (TUCKER and McCANN, 1980) that JENNESS' (1960) interpretation of glacial limits in eastern Newfoundland is more appropriate than GRANT's (1977) reconstruction.

METHODS

In the descriptions that follow the term bench refers to a platform cut in bedrock, and terrace to an erosional feature cut in unconsolidated material. The heights of these wave-cut landforms were measured at the foot of the backing cliff or break of slope. In the case of benches capped by surficial material where this feature was obscured, the level of the highest exposed portion the rock platform was then recorded. Outwash deposits and deltas, graded to former sea level positions, were measured at their leading edges, unless suitable exposures were present. Then the angular unconformity between topset and foreset beds was considered to represent the marine limit. Raised beach ridges were measured at two sites and wash limits at several localities.

All the elevations cited were measured by making at least two traverses from a convenient datum point with a barometric altimeter, except for sites 12, 13, 28, 32 and 34, where profiles were surveyed from the

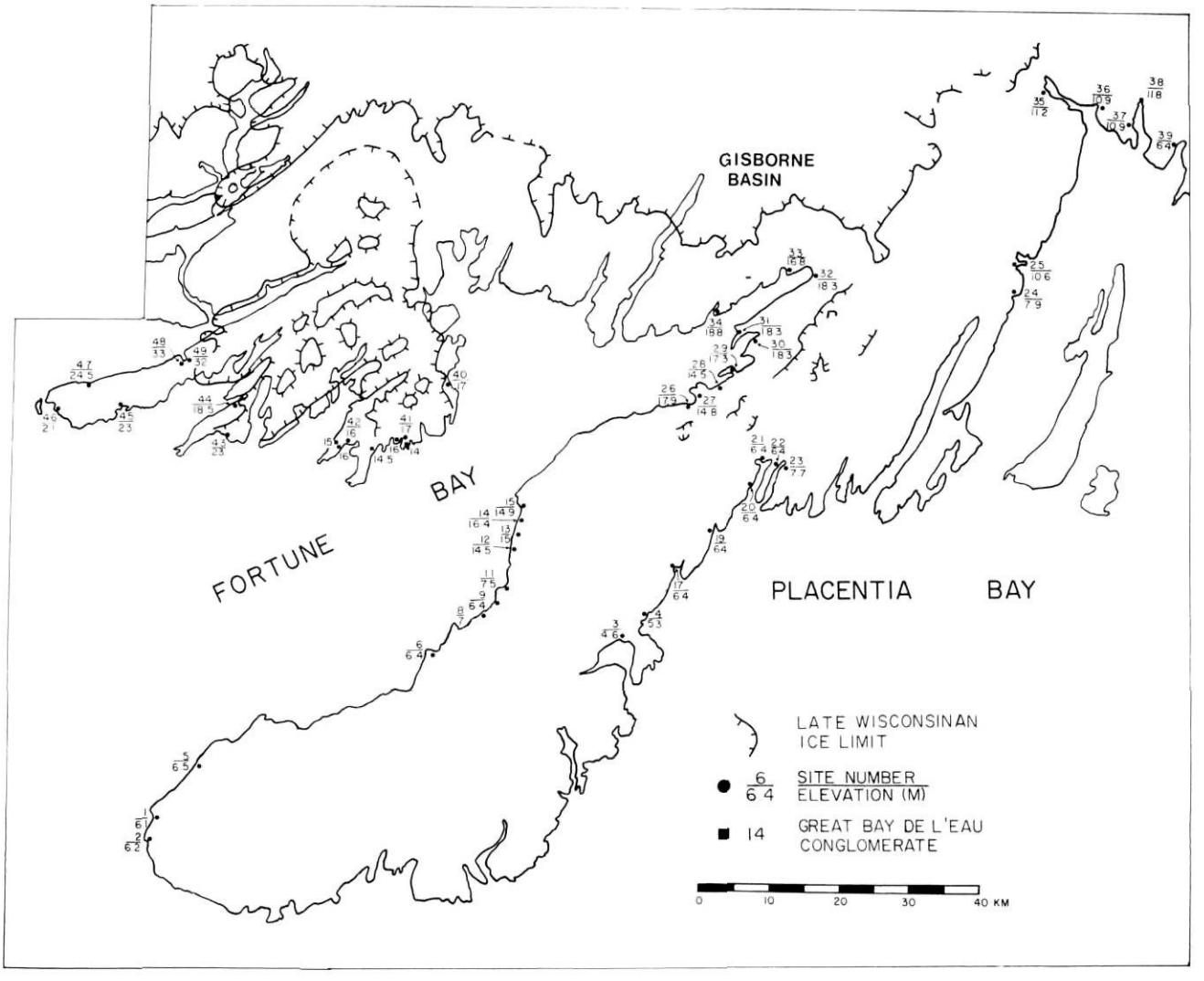

FIGURE 3. Late Wisconsinan ice marginal position and elevations of the Late Wisconsinan marine limit in the Burin-Hermitage area of southern Newfoundland. The datum is higher, high water level of large tides.

Localisation du front glaciaire et des altitudes de la limite marine au Wisconsinien supérieur dans la région de Burin-Hermitage, au sud de Terre-Neuve. Le point de référence est le niveau le plus élevé des eaux au moment des plus fortes marées.

modern beach inland across either a series of raised beach ridges or deltaic deposits using a surveyors level and staff. The datum for the measurements on the Burin Peninsula was higher, high tide level of large tides, as represented by the highest, well-defined debris level on the modern beach. The datum in the Hermitage area was still water level at the time of observations, and the measurements have been converted to elevations above higher, high tide level of large tides using the appropriate tide tables (CANADIAN HYDROGRAPHIC SERVICE, 1978). Present tidal range at mean and large tides is 1.3 — 1.7 m, and 1.8 — 2.4 m, respectively. All the measurement sites and elevations are listed in Tables I and II, with appropriate 1 : 50,000 map sheet numbers and six-digit UTM coordinates.

MARINE BENCHES
(Table I, Figure 2)

Marine benches, cut in different types of bedrock at various elevations up to 50 m, occur around the coastline of the Burin Peninsula. However, with the exception of a well-defined, low level feature, which occurs at numerous localities and can in places be traced more or less continuously for several kilometres along the shore, the relationships between many of the benches remain obscure. Low level benches between 4.5 and 4.9 m at 23 widely spaced localities are considered to represent one ancient rock shoreline. Benches at a further 15 sites, at various elevations between 3.0 and 5.9 m, are also included with this group. There is no indication that the shoreline so defined is tilted. All 38 sites are identified in Table I and Figure 2. The repeated occurrence of this bench and its local continuity are well displayed along the relatively accessible southern coast of the peninsula between Parkers Cove (site 39) and Wreck Cove (site 2). It occurs consistently at 4.6 — 4.9 m along the coast between Jean de Baie and Burin Inlet (sites 14, 15, 16, 17, 22, 23, 24, 26). In St. Lawrence Harbour to the southwest it can be traced intermittently round the head of the bay (site 11, 4.9 m), from which point it rises slightly towards the bounding headlands (sites 10 and 12, at 5.4 and 5.0 m, respectively). It is well developed also at the head of Fortune Bay (sites 52, 53, 54, 56, 57) and in the vicinity of Swift Current (sites 45, 46, 48).

The width of the benches varies from only 2 m at Taylor's Bay (site 6) to several tens of metres at Salmonier on Burin Inlet (site 15). The bench surface, except at exposed locations subject to marine washing, is usually well striated and overlain by till. The till cover is of variable thickness, texture and age, but can be assigned in many places to the "Fortune Bay" event, considered by TUCKER and McCANN (1980) to represent an all-encompassing glaciation of the Peninsula by ice from the north during Early Wisconsinan times. This suggests that the shoreline may have been formed in the preceding Sangamonian Interglacial.

In the Hermitage area, as on the Burin Peninsula, marine rock benches occur at a variety of elevations and correlation is difficult. The most interesting locations are Deadman's Bight, southwest of Harbour Breton (site 76), and the southeast coast of Great Bay de l'Eau between Wreck Cove (Tibbos Hill) and Coomb's Cove (sites 71 — 74). At Oxford Point in Deadman's Bight there is an ice-moulded, striated, bench at 10.5 m, overlain by till and Late Wisconsinan deltaic sediments. The bench was originally described by WIDMER (1950) and noted by GRANT (1975), both of whom suggested it was Sangamonian in age. Benches of similar elevation but lacking surficial deposits also occur on nearby Black and Hill Islands, and another, at 4 m, approximately 1 km southwest of Oxford Point. Only three other localities were recorded in the Hermitage area where old, low level benches occur which might be correlated, on the basis of elevation, with the well defined rock shoreline of the Burin Peninsula. These are Rocky Harbour (site 75, 5 m bench overlain by till), St. Johns Bay (site 69, benches at 5 m and 7 m) and Pool's Cove (site 58, 4.5 m bench). GRANT (1975, Fig. 1) identified two sites, in addition to Oxford Point, where interglacial marine benches occur beneath till, east of Pass Island (near site 81) and near Gaultois (west of site 83), but careful examination of both areas did not substantiate these observations.

Along the coast between Wreck Cove and Coomb's Cove the bedrock is a poorly lithified, upper Devonian conglomerate (Great Bay de l'Eau conglomerate; ANDERSON, 1965), and there is a pair of clearly defined benches, at 15 — 16 m and 29 — 36 m, each backed by rock cliffs (sites 71 — 74). There is a marked difference in the character of the two benches. The flat surface of the lower is little dissected and supports several sea stacks; the backing cliff exhibits several caves and wave-cut notches. In contrast the upper bench is highly dissected, resembling the surrounding countryside developed in similar bedrock, and the backing cliff is indistinct in many places. There are no glacial deposits or indications of glacial erosion on either bench and the area is considered to have been ice-free during the Late Wisconsinan (LECKIE, 1979). The lack of dissection of the lower bench, which is present at similar elevations at various localities as far east as English Harbour West (sites 65 and 66), and the preservation of sea stacks, caves and notches, indicate that it represents a recent episode of marine erosion. For this reason it is grouped with the late- and post- glacial terraced features discussed separately below. Isolated benches backed by poorly developed cliffs, occur at various elevations be-

TABLE I

Elevations of Raised Marine Benches

Site	Map	Reference	Elevation (m)
1	1L/13	779 046	8*.5
2	1L/13	783 964	3.7Δ
3	1L/13	789 951	3.4Δ
4	1L/13	918 887	3.1Δ, 10.1
5	1L/13	951 893	3.1Δ
6	1L/13	984 912	3.6Δ
7	1L/13	019 920	4.8Δ
		024 924	42.3
8	1L/13	087 971	4.6Δ
		089 966	7.6
9	1L/13	111 995	3.1Δ
10	1L/14	220 929	5.4Δ
11	1L/14	235 963	4.9Δ
12	1L/14	258 952	5.0Δ
13	1L/14	338 020	4.3Δ, 12.2
14	1M/3	371 099	1.5, 4.9Δ
15	1M/3	359 133	4.8Δ
16	1M/3	381 090	4.9Δ
		382 088	18.3
17	1M/3	392 100	14.3
		398 107	4.9Δ, 12.2
18	1M/3	398 120	17.1
19	1M/3	414 132	7.6
20	1M/3	437 167	3.5Δ, 12.0
21	1M/3	463 188	41.0
22	1M/3	448 223	4.8Δ
23	1M/3	435 242	4.8Δ
24	1M/3	418 277	4.6Δ
		434 290	7.6
25	1M/3	481 262	6.7
26	1M/3	468 315	4.5Δ
27	1M/4	823 085	4.8Δ
		826 090	6.1
28	1M/4	865 139	7.6
29	1M/4	109 212	2.5
30	1M/3	155 250	2.9
31	1M/3	227 313	1.7
32	1M/6	273 360	16.8, 24.7
33	1M/6	281 410	4.6Δ
34	1M/6	292 495	2.7, 3.4Δ, 6.1, 9.5, 24.7
35	1M/6	298 510	5.9
36	1M/7	517 399	1.5, 3.1Δ
37	1M/7	573 457	6.4, 13.0
		574 457	18.3
		574 465	4.5Δ
38	1M/7	595 473	3.5Δ
		595 474	5.5Δ, 22.0
39	1M/7	618 508	3.0Δ
		624 513	5.5Δ, 6.4
40	1M/9	928 719	13.4
		930 724	6.7
41	1M/9	999 793	8.3
		003 792	10.7
42	1M/9	996 788	15.8
43	1M/9	015 834	7.6
		015 836	11.6
44	1M/16	080 070	13.0
45	1M/16	088 064	4.6Δ
46	1M/16	125 034	4.5Δ
47	1M/16	159 045	22.0
48	1M/16	169 046	4.8Δ
		172 046	4.5Δ
49	1M/10	539 635	1.5
50	1M/10	558 655	18.5, 50.3
51	1M/10	594 684	28.9
52	1M/10	623 695	1.5, 4.9Δ
53		624 731	4.8Δ
		629 733	6.7
54	1M/10	610 728	4.6Δ
55	1M/10	589 720	6.7, 9.4
		591 715	42.6
56	1M/10	659 823	4.6Δ
		622 827	23.2
57	1M/10	584 776	28.0
		589 777	4.6Δ
58	1M/11	173 826	4.5Δ, 15.0
59	1M/11	180 812	16.0
60	1M/11	189 716	10.0
61	1M/11	188 653	12.0
62	1M/11	200 644	16.0, 23,0, 27.0, 43.0
63	1M/6	190 602	15.0
64	1M/6	181 602	20.0
65	1M/5	123 559	14.0*
		128 559	14.0*
		131 559	14.0*
66	1M/5	119 579	17.0*
67	1M/5	083 558	31.5
68	1M/5	059 538	8.0
69	1M/5	058 548	5.0
70	1M/5	054 570	8.0
71	1M/5	038 565	16.0*, 19.0*
72	1M/5	032 563	15.0*, 36.0*
73	1M/5	046 611	11.5*, 19.5*
74	1M/5	052 613	16.0*, 32.0*
75	1M/5	906 585	5.0Δ
76	1M/5	867 575	5.0Δ, 10.5
77	1M/12	830 666	6.0, 32.0
78	1M/12	802 642	23.5
79	1M/12	777 617	37.5
80	1P/9	728 615	28.5
81	1P/8	618 608	23.5
82	1P/9	661 633	31.0
83	1M/12	873 725	26.5

Δ Sangamonian Bench.

* Benches developed in Bay de l'Eau conglomerate.

tween 22.5 m and 36.5 m along both coasts of the southwest peninsula of the Hermitage area, and may represent a single rock shoreline equivalent to the upper bench on the Wreck Cove-Coomb's Cove coast. The various bench levels recorded in the southeast Hermitage area, including the sequence of five at 15, 22, 26, 42 and 63 m near Belleoram (site 62), do not suggest any correlations.

RAISED SHORELINE FEATURES IN UNCONSOLIDATED SEDIMENTS
(Table II, Figure 3)

Table II lists the elevations of raised shoreline features measured in the Burin — Hermitage area which are developed in unconsolidated sediments and are considered to be Late Wisconsinan or younger in age. A series of ill-defined terrace levels and graded outwash deposits within the Marystown — Garnish lowland (Burin Peninsula between sites 23 and 31) and along the Fortune Bay coast to the north, have been assigned to the Mid-Wisconsinan (TUCKER, 1979 a and b; TUCKER and McCANN, 1980) and are not considered here. Figure 3 shows the elevations of those features considered to represent the Late Wisconsinan marine limit and the position of the Late Wisconsinan ice margin.

The Late Wisconsinan and younger raised marine shoreline sites fall into two categories — 1) deltas and outwash deposits, and 2) terraces and beach deposits. Most important are those sites where raised glaciofluvial deltas and graded outwash deposits provide evidence of marine action and relative sea level during the period

TABLE II
Elevations of Raised Shoreline Features in Unconsolidated Material

Site	Map	Reference	Elevation (m)
1	1L/13	782 034	6.1†
2	1L/13	775 997	3.3, 6.2†
3	1M/3	414 278	4.6†
4	1M/3	469 315	5.3†
5	1M/3	803 070	3.7, 6.5†
6	1M/3	180 273	6.4†
7	1M/3	205 308	3.7
8	1M/3	235 319	7.0†
9	1M/3	253 333	6.4†
10	1M/4	050 189	2.8
11	1M/6	277 363	7.5†
12	1M/6	283 408	12.2
		283 413	9.5
		284 413	14.5†
13	1M/6	285 426	4.6
		288 424	15.0†
		289 430	15.0
14	1M/6	288 450	4.5, 16.4†
15	1M/6	292 495	14.9†
16	1M/6	299 509	11.2
17	1M/7	518 398	6.4†
18	1M/7	567 420	2.1
19	1M/7	572 460	6.4†
20	1M/7	623 513	6.4†
21	1M/7	637 553	6.4†
22	1M/7	663 546	6.4†
23	1M/7	670 550	6.7
		670 555	7.7†
24	1M/9	995 792	7.9†
25	1M/9	080 838	7.6
		015 836	10.6
26	1M/10	536 629	17.9†
27	1M/10	542 638	6.7
		542 640	14.8†
28	1M/10	558 652	6.4
		568 654	14.5†
29	1M/10	590 675	4.6†
		607 685	17.3†
30	1M/10	624 695	7.6
		629 698	18.3†
31	1M/10	603 730	18.3†
32	1M/10	712 817	6.1
		723 817	16.8
		726 823	14.6
		731 825	18.3†
33	1M/10	665 832	16.8†
34	1M/10	589 776	18.8†
35	1M/16	057 083	8.5
		035 108	11.2†
36	1M/16	113 059	10.9
		117 063	8.5
37	1M/16	163 044	4.9
		170 031	10.9†
38	1M/16	182 063	11.8†
		183 068	6.4
		183 070	4.8
39	1M/16	238 015	6.4†
40	1M/11	188 651	17.0†
41	1M/5	122 573	17.0†
42	1M/5	043 568	16.0†
43	1M/5	865 576	23.0†
44	1M/12	883 619	18.5†
45	11P/9	719 615	23.0†
46	11P/8	627 593	21.0†
47	11P/9	661 633	24.5†
48	1M/12	806 674	33.0†
49	1M/12	813 677	32.0†

† Late Wisconsinan marine limit

when ice stood at the Late Wisconsinan glacial limit. These include Deadman's Bight (site 43) in the Hermitage area and several sites at the head of Fortune and Placentia Bays on both coasts of the upper Burin Peninsula. The relationships between glacial, glaciofluvial, deltaic and beach deposits are particularly clear in a long coastal section at Deadman's Bight. The marine limit is defined by a deltaic topset-foreset contact at 23 m, and a distinct terrace at 11.5 m represents a later phase of marine reworking of the older deposits. That part of the coastal section cut into this terrace reveals up to 8.5 m of beach sediments. Poorly developed terraces have also been cut at other levels below the marine limit at this locality. At Jacques Fontaine (site 28) there is a similar ice contact delta at 14.5 m, which developed at the margin of a small, isolated patch of Late Wisconsinan ice. Seaward of the raised delta at Jacques Fontaine and at about the same elevation there is a raised sea stack and marine bench cut in competent bedrock. These features, which do not appear to have been affected by glaciation, may represent the effects of Late Wisconsinan marine erosion in trimming and re-excavating a much older shoreline.

At other locations in this group of sites the Late Wisconsinan ice limit was well inland and the elevations represent measurements of graded outwash deposits which reached the coast. The highest levels of marine erosion and reworking of the outwash gravels are well defined at English Harbour East (site 34, 18.8 m), Grand le Pierre (site 33, 16.8 m) and Terrenceville (site 32, 18.3), at the head of Fortune Bay, where there are also contemporaneous terraces cut in older drift (sites 30 and 31, both at 18.3 m). On the southeast (or Placentia Bay) coast of the upper Burin Peninsula, Late Wisconsinan graded outwash and raised deltas occur at three widely-spaced localities — in the vicinity of Swift Current (sites 35 — 38, 10.9 to 11.8 m), at Great Sandy Harbour (site 25, 10.6 m) and the head of Bay de l'Eau (site 23, 7.7 m). The marine limit so defined is several metres below the limit on the head of Fortune Bay and declines in elevation to the southwest. The Swift Current outwash is the largest in the study area and is a complex feature. The overall surface slopes southeastwards down the estuary from 12 m to 8.5 over a distance of 10 km, but is interrupted by locally developed terraces and deltas and fans from small side streams. The heights cited above (sites 35 — 38) were measured on erosional terraces which are underlain in part by marine-worked gravels.

The second category of sites shown on Figure 3 includes coastal terraces and raised beach ridges developed in areas of locally abundant drift which is older than Late Wisconsinan. In most cases, wave-reworked sediments, derived from the older drift, form the surface of the terraces, a feature which is best seen at Pass Island Tickle (site 46) and Mose Ambrose (site 41) in the Hermitage area. The shoreline(s) defined by the various terraces and beach deposits is rarely continuous for more than 0.5 km along the coast, but it is possible to trace a single raised strandline for some 25 km along the northern shore of Connaigre Bay between Pass Island Tickle (site 46) and the through valley leading to the town of Hermitage (sites 48 and 49). The marine limit, which may be up to a kilometre inland, rises from 21 m at Pass Island to 33 m near Hermitage. This feature, together with the deltaic marine limit at Deadman's Bight (22 m) and the lower rock bench developed in easily — eroded conglomerate in the Wreck Cove — Coomb's Cove area (14 — 16 m), discussed above, provides an indication of postglacial emergence in the Hermitage area.

On the Placentia Bay coast of the Burin Peninsula erosional terraces at 6.4 m in Boat Harbour (site 21) and Bay de l'Eau (site 22) are contemporaneous with the Bay de l'Eau outwash at 7.7 m (site 23), and traces of the same shoreline were recorded at declining elevations southwestwards as far as Mooring Cove (site 3, 4.6 m) at the entrance to Burin Inlet. No raised shoreline features developed in unconsolidated materials were found along the south coast of the Peninsula between this point and the Dantzic Cove area (sites 1 and 2) in the extreme southwest, where there are distinct terraces at 6.1 m and 6.2 m cut in a variety of older drift deposits. On the Fortune Bay coast of the Peninsula, south of the influence of Late Wisconsinan ice, the marine limit is represented by a variety of raised shoreline features which increase in elevation northwestwards from 6.4 m at Fox Hummocks (site 6) to 14.9 m at Point Enragée (site 15). The rather abrupt increase in height between site 11 (7.5 m) and site 12 (14.5 m), over a distance of only 6 km, is partly explained by the nature of the shoreline features measured at the two sites. At site 10 the marine limit is represented by a terrace in a protected embayment, whereas at site 12, and at site 13, it is represented by the crest of the highest of series of raised beach ridges on an exposed section of coast.

RECENT SUBMERGENCE

There are no postglacial elevated terraces along the extreme south coast of the Burin Peninsula and radiocarbon dates on coastal organic deposits found at two localities (see Fig. 4) are indicative of recent submergence. At site A, 0.5 km south of Little St. Lawrence, peat containing wood fragments, is exposed below the sand and gravel of the modern foreshore, 1.7 m below the higher, high water level of large tides. The peat has been dated at 970 ± 50 yr BP (GSC -2569) and the wood, which is birch *(Betula sp.)* and balsam fir *(Abies balsama)*, at 1080 ± 50 yr BP (GSC -2617). At site B, 5.2 km

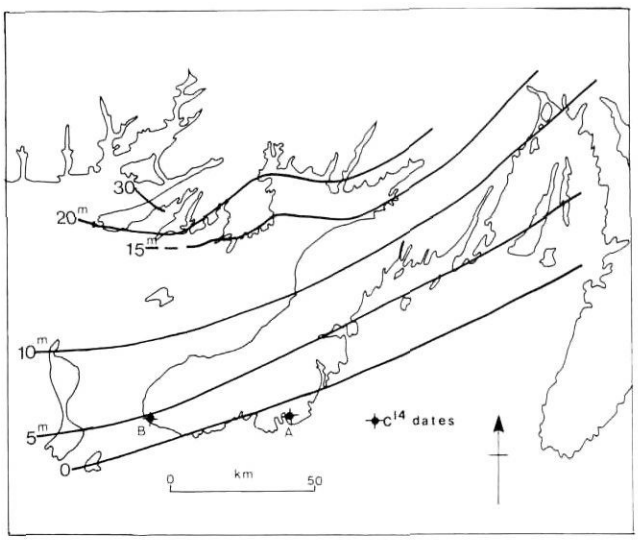

FIGURE 4. Isopleths of postglacial emergence in the Burin-Hermitage area of southern Newfoundland and the islands of St. Pierre and Miquelon.

Isoplèthes de l'émersion post-glaciaire dans la région de Burin-Hermitage au sud de Terre-Neuve et aux îles de Saint-Pierre et Miquelon.

north of Point May, a peat deposit containing branches of spruce *(Picea sp.)* and larch *(Larix sp.)*, at 1.0 to 1.2 m above the level of higher, high water of large tides, is being eroded by the sea. The peat has been dated at 5360 ± 70 yr BP (GSC -2613) and the wood at 3620 ± 60 yr BP (GSC -2580). These data suggest a continuing pattern of marine encroachment and coastal submergence along this southernmost mainland coastline of the study area.

DISCUSSION AND CONCLUSIONS

As indicated in the introduction, this account should be viewed in the context of our regional interpretation of Quaternary events, and as reconnaissance survey of raised shoreline features over a large area which has been little explored in terms of its Quaternary history. Readers familiar with the numerous studies of similar phenomena in Scotland will be aware of the many changes in interpretation (of both glacial limits and the ages and correlations of raised shoreline sequences) which have been a feature of the work over the last twenty years. They will recognize that the problems to be faced in further work in southern Newfoundland are exactly analogous to those which have occupied recent workers in Scotland, the most important of which concern the ages of marine benches cut in bedrock. This problem is compounded by the likelyhood that individual benches have been produced by two or more, widely spaced, phases of marine erosion and by uncertainties about the rates and processes of rock platform and cliffline erosion (for a discussion of some of these problems in Scotland see McCANN, 1966, 1968; GRAY, 1974; SISSONS, 1974; SISSONS and DAWSON, 1981). The fragmentary nature of the evidence also mitigates against the reconstruction of ancient rock shorelines, and in southern Newfoundland the absence of firm dates, even for Late Wisconsinan events, poses an additional problem.

With these limitations in mind the following conclusions are offered:

a) All of the raised shoreline phenomena in the Burin — Hermitage area, except at the head of Bay d'Espoir, are marine features. The only evidence for a large ice-dammed lake in the Burin — Hermitage area comes from the northern Bay d'Espoir where there are raised lacustrine deltas and associated strandlines at about 22 m (LECKIE and McCANN, in press). WIDMER's (1950) hypothesis concerning the existence of massive ice-dammed lakes in not correct.

2) Raised marine benches occur throughout the area at various elevations from just above modern sea level to more than 50 m. Along the southeast coast of the Burin Peninsula there is a ubiquitous bench, which occurs consistently at an elevation of 4.5 to 4.9 m in what might be considered the type localities for this feature between Marystown and Burin Inlet. This bench and similar features at elevations between 3.0 and 5.9 m, at numerous other localities throughout the study area, are considered to represent a single horizontal rock shoreline. Many of these benches show evidence of glacial erosion and are overlain by till, and it is suggested that the shoreline was formed during an interglacial period, possibly the Sangamonian. Of the higher benches, some of those developed in easily eroded conglomerate on the Wreck Cove — Coomb's Cove coast of the Hermitage area are considered to be Late Wisconsinan in age.

3) The contemporaneity of raised deltas and graded outwash at several sites across the northern part of the study area, originally suggested by JENNESS (1960), and the relation of these deposits to the Late Wisconsinan ice marginal position, have provided a starting point for a new construction of isopleths of post-glacial marine emergence (Fig. 4). The highest raised terraces and beach deposits along both coasts of the central and lower Burin Peninsula are considered to be generally contemporaneous with the coastal outwash features further north, and to indicate the maximum extent of Late Wisconsinan marine submergence.

4) The pattern of post-glacial emergence so defined (Fig. 4) is based on many more datum points than the earlier reconstructions by JENNESS (1960) and WIGHTMAN and COOKE (1978), and utilizes radiocarbon dates from submerged and eroding terrestrial organic deposits to validate the position of the zero isobase. The pattern differs from the previous reconstructions in the following respects:

a) The position of the 30 m isopleth of WIGHTMAN and COOKE (1978), the 100 ft. isopleth of JENNESS (1960), is shifted 50 km to the south. The southward deflection of the isopleths in the Hermitage area reflects the presence of a separate Late Wisconsinan ice mass in this area.

b) The 10 m isopleth is shifted northwards from the position suggested by WIGHTMAN and COOKE (1978), and extends southwestwards from Swift Current to northern Miquelon. The extension of the 10 m and 5 m isopleths to St. Pierre and Miquelon is based on the findings of TUCKER (1979b).

c) The zero isopleth occupies an intermediate position between the two earlier suggested positions. This reflects the absence of terraces along the south coast of the Burin Peninsula and the evidence of recent submergence.

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